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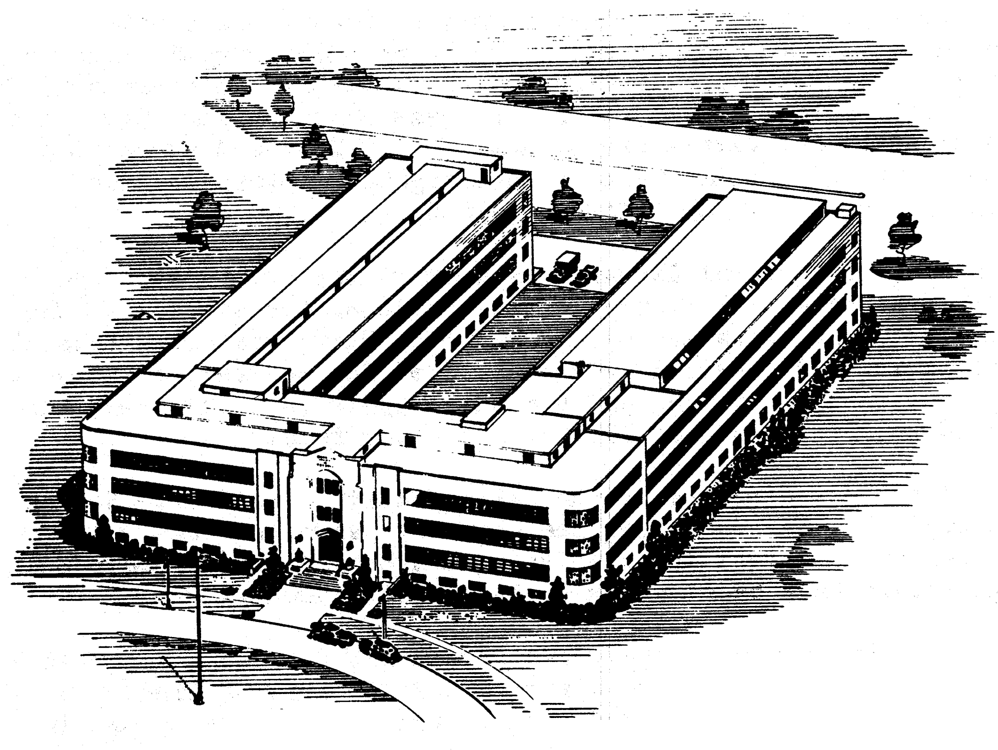

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By

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The waste from potato starch factories creates a problem that has been given considerable attention in recent years. During World War II, the water supply of the Army Air Base at Presque Isle, Maine, was polluted at times by starch factory wastes dumped into the stream above the Base. The Army set up a mobile laboratory at a Presque Isle starch factory in 1944 to study this problem. Various methods were considered for treating the two wastes, which consisted of extracted pulp and processing water ("protein water") (1). The Army technicians obtained promising results in dewatering the pulp by vacuum filtration and by roller pressing. The protein water was treated by chemical coagulation, aeration plus coagulation, high-rate biofiltration, sand filtration, chlorination, and heat coagulation. Removal of solids, reduction in biochemical oxygen demand (B.O.D.), and comparative costs of equipment and treatments were investigated. Biofiltration was deemed the most effective of any treatment tried.

The Eastern Regional Research Laboratory has studied the composition and treatment of starch factory wastes for a number of years. The volume and concentration of wastes discharged from Maine factories have also been investigated (2). Methods were developed for recovering waste pulp by pressing and thermal drying, and a cost analysis (3), indicated that the pulp could be dried economically for livestock feed.

A pilot plant operated by the Maine Institute of Potato Starch Manufacturers at Mapleton, Maine, during the past few years has tested various methods and pieces of equipment for dewatering and drying waste potato pulp. Some feeding trials have been made with the dried product.

In 1946, byproduct recovery was investigated under a contract let by the Maine Institute of Potato Starch Manufacturers. Engineers of the contracting laboratory[1] considered coagulating the protein by passing the processing water through a heat exchanger. They proposed to partly dewater the coagulated protein, collected on a screen above a layer of waste pulp, and then complete the dewatering by pressing, followed by thermal drying.

Only about 40 percent of the nitrogen in protein water can be coagulated; the remainder consists of compounds too low in molecular weight to be coagulated. Coagulated protein is difficult to dewater and dry. The electrolytes in protein water can be removed by adsorption methods, and the entire solubles content can be recovered by evaporation of the water, but the cost of either procedure would be prohibitive.

It has been suggested that the protein water be "lagooned". This practice has been used successfully by canneries that operate only during a short season in warm weather. Some of the impounded liquid seeps into the soil

1/ Arthur D. Little, Inc., Cambridge 42, Massachusetts slowly; the remainder is passed into streams after the pollution load has been reduced. If desired, the sludge, consisting mostly of microorganisms propagated in the lagooned waste, is then removed. It might be more difficult to carry out this practice in the potato starch industry in Maine and Idaho because many of the factories are frequently located in populated areas, where odors from lagooned waters would be objectionable. Moreover, since much of the operating season is in cold weather, it would be necessary to impound wastes during the winter and wait for the following spring and summer for the natural microbiological action to proceed.

In Holland, protein water is sprayed on fields after the potatoes are harvested (4). This procedure would probably be impractical in Maine and Idaho, principally because of the low temperatures prevailing during the starch producing season. In addition much of the terrain in Maine is too hilly for spray irrigation.

Since the various methods previously considered for disposing of or recovering protein water have their drawbacks, it was decided to explore microbiological treatment of this waste, with the objective of reducing the solubles to a level that would not cause stream pollution.

Composition of Wastes

Waste potato pulp from a starch factory contains about 4 percent total solids. On the dry basis, these consist of 45-55 percent starch and 6-12 percent protein; the remainder is principally pectin, hemicellulose, and cellulose. One sample, after it was dewatered by squeezing the liquor through cheesecloth and drying with mild heat, had the following percentage composition: Moisture, 4.5; starch 54.6; crude fiber, 15.6; uronic acid anhydride, 16; pectin, 12; pentosans, 9.5; protein, 5.9; ash, 1.0; fat, 0.4; sugars, trace. It will be noted that the percentages of these constituents total more than 100. Undoubtedly, there is overlapping in the uronic anhydride and pectin and, perhaps also, the pentosans.

A factory producing 10 tons of starch daily discharges 4000-4500 pounds of pulp solids. Several of the more recently established plants produce 25-50 tons of starch a day.

Protein water contains about 1 percent total solids. On the dry basis, they consist of 50-65 percent nitrogen compounds and 10-15 percent starch; the remainder is fibrous material, soluble inorganic substances, and soluble nitrogen-free organic compounds. A 10-ton starch factory discharges 4,500-6,500 pounds of protein water solids daily, which is somewhat more than the pulp solids.

Polluting Effect of Potato Wastes and Study of Its Alleviation

Potato starch factory waste has a high polluting effect because of its content of organic matter. The chemical oxygen demand of the total waste as it leaves the factory is about 12,000 parts per million, which is 60-70 times that of domestic sewage. This means that 12 pounds of oxygen is needed for the complete oxidation of the organic matter in 1000 pounds of waste (about 120 gallons). After the suspended solids are removed, the demand is decreased to 4000-4500, about one-third of the original. Our data show that the soluble organic material may be converted to an insoluble form by the action of microorganisms and removed by suitable means (settling, filtration, or centrifugation), leaving an effluent with less polluting effect. The recovered solids may possible find use as a fertilizer or a feed.

The total waste, containing extracted pulp and protein water, was used in most of our experiments. It was anticipated that a portion of the carbohydrate of the pulp would be metabolized in the production of microbial cells. Furthermore, laboratory experiments showed that the mixture of pulp and microbial cells present at the end of the aeration period filtered more easily than pulp alone. In treating wastes from canneries, potato chip plants, and frozen food processing plants, it may be advisable to screen off the coarse suspended solids, such as potato skins and trimmed sections, before attempting to ferment the potato solubles.

Experimental

In evaluating various procedures in the microbial oxidation of starch factory wastes, we employed the chemical oxygen demand method (C.O.D.) used in previous work at this Laboratory on dairy waste (5). The C.O.D. values are approximately equal to 20-day B.O.D. values.

Conversion wastes to microbial cells was carried out both batchwise and continuously in Waldhof-(6) and Humfeld-type (7) fermentors of 5- to 20-liter capacity. An abundant supply of air was provided during the fermentations. The rate of aeration was usually about one fermentor volume per minute. Foaming is a serious problem in handling potato wastes. The Waldhof-type fermentor with its centrifugal agitator was effective in preventing foam from climbing the walls of the container. Foam control agents, such as "DC Antifoam A"[2], also aided considerably in reducing the foam.

The waste material used was prepared in a potato starch pilot plant and frozen in 1-gallon containers immediately after preparation. As required, portions of the waste were thawed and then kept at 2° C. before being pumped to the fermentor in the continuous operations. The conversion processes were ordinarily carried out at 30° C. So much heat was evolved that it was necessary to cool, rather than heat, the fermentor.

Results

Since suspended solids can be removed by various means, the problem is actually to convert organic solubles into removable solids and volatile matter. The C.O.D. of the supernatant liquor from a filtered sample was found to be lower that that from a centrifuged one, probably because centrifuging did

2/ Mention of products does not imply recommendation or endorsement by the U. S. Department of Agriculture over similar products not mentioned.

not remove all the organic material in suspension. For example, a sample of untreated potato waste liquor had C.O.D. values of 4050 after filtration and 4350 after centrifugation. Samples taken during the propagations often exhibited a much greater difference.

MIXED WASTES. Several experiments were carried out on the mixed wastes. In the first, a mixed culture from decaying potatoes was used as the inoculum. The waste liquid was pumped through a 5-liter Waldhof-type fermentor at the rate of 2 fermentor volumes per 24 hours. After 8 days of continuous fermentation, the C.O.D. of the supernatant liquor had decreased to about 870 units (Table I).

Table I. Continuous Conversion1/ of Waste Inoculated with Culture from Decaying Potatoes

	C. O. D.	
Time, days	Centrifuged	Filtered
1	2498	2/
2	1173	2/
3	1931	2/
4	2688	1060
7	2637	1104
8	2/	973
9	2/	867

1/ Flow rate, 2 fermentor volumes per day. Original C.O.D. of filtrate, 4050.

2/ Not determined.

The C.O.D. values show that in this continuous process equilibrium was probably reached by the eighth day. Because of a temporary shortage of raw material in the liquid state, the flow to the fermentor was stopped at this point. The fermentation was then allowed to proceed batchwise for 48 hours without the addition of new waste. After 24 hours, the C.O.D. of the filtered waste liquor had decreased to 427. By 48 hours, however, the C.O.D. had increased to 1640, perhaps because of the autolysis of cells.

In another type of experiment, fermentation was carried out batchwise; an "activated" or aerated sludge consisting of microorganisms that thrive in and had become adapted to the waste substrate was used as the inoculum. The process was started with 12 liters of liquid in a 20-liter Humfeld-type fermentor. As shown in Table II, 8 liters of liquid was added after 24 hours. After 72 hours of the 2-step fermentation, the C.O.D. had been reduced to 627.

Table II. Batch Conversion of Waste

Original charge: 9 l. waste liquid 1/ with 3 l. from previous propagation 2/ used as inoculum.

After 24-hours: 8 l. fresh waste liquid 3/ was added.

Time, hrs.	Temp., °C.	pH	C.O.D. Centrifugate	C.O.D. Filtrate
24	34	8.25	2613	1500
48	34	8.20	3413	1173
72	30	8.40	3311	627

1/ C.O.D. of filtrate, 3900.
2/ C.O.D., 430.
3/ C.O.D., 3900.

Inoculation with a soil culture was tried in a continuous fermentation (Table III) to compare the results with those previously obtained with a culture from decaying potatoes. After an induction period of 19 hours, waste was pumped to the fermentor at the rate of 1.4 fermentor volumes per day. After 6 days' fermentation, the C.O.D. of the filtrate had decreased to about 600. Since the value was slightly more than 700 after 5 days, it is believed that equilibrium conditions were obtained by the seventh day.

Table III. Continuous Conversion 1/ of Waste

Original charge: 15 l. waste liquid, 2/ together with soil inoculum; aerated for 19 hours before the continuous process was started.

Time, Hrs.	Temp., °C.	pH	C.O.D. of Filtrate
19	28	8.9	2490
48	28	8.7	1117
72	30	8.8	1270
96	30	8.8	996
120	30	8.8	710
144	30	8.8	613

1/ Flow rate, 28 l. per day through 20-l. fermentor.
2/ C.O.D. of filtrate, 3800.

An inoculum consisting of a mixture of yeast (*Torulopsis utilis*) and a fungus (*Aspergillus niger*) gave erratic results, believed to be due in part to pH changes. It was shown, however, that appreciable reduction of C.O.D. is possible with this inoculum. Waste was fed into a 5-liter Waldhof-type fermentor at the rate of 1 fermentor volume a day. After 24 hours, the C.O.D. had decreased to 843. Later the pH rose from its original value of 3.7, and the C.O.D. increased. Control of the pH within the range of 3.0-3.8 would possibly lead to appreciable reduction of C.O.D. with this inoculum.

PROTEIN WATER ALONE. Protein water completely free of waste pulp was investigated to obtain data on reduction of C.O.D. by microbial growth followed by protein coagulation. Such a dual treatment resulted in the lowest C.O.D. values of all. In one experiment in this series, 300 ml. of protein water (C.O.D., 4000) was inoculated with 50 ml. of activated sludge from a previous batch propagation originally inoculated with soil. The mixture was shaken for 24 hours at room temperature to permit thorough aeration. After this time, the waste filtrate had a C.O.D. value of 1087. After acidification with sulfuric acid to pH 3 and protein coagulation, the filtrate had a C.O.D. of 338.

In another set of similar experiments, 300 ml. of protein water was inoculated with 50 ml. of activated sludge from a previous propagation. After 22 hours, the filtrate of one sample had a C.O.D. of 862, and that of another was 752. Acidification to pH 3 further reduced the C.O.D. of the filtrate to 188 and 196, respectively.

The problems connected with the microbiological treatment of potato-processing wastes are apparently similar in many respects to the problems connected with the microbiological treatment of dairy waste. In the latter, studied extensively at this Laboratory, the highly polluting, soluble waste solids with a high oxygen demand have been converted to insoluble bacterial cells, leaving the remainder of the wastes with a low oxygen demand (8). Since such treated dairy waste has a low polluting effect, the suggestion has been made that, under certain conditions, it be discharged directly into streams. To evaluate these laboratory findings on dairy waste pilot-plant studies will be made at the Pennsylvania State College under a contract with the Eastern Regional Research Laboratory.

Summary and Conclusions

Stream pollution caused by potato starch factory wastes has been studied by several organizations during the past 10 years. Research ~~which~~ has demonstrated that the pulp can be recovered as a byproduct without undue trouble and expense. Recovery of the soluble organic substances present in dilute form in the processing water, however, presents an unusually difficult problem because of the high costs of most processes.

In the study reported here, several types of microbiological treatment designed to reduce the oxygen demand of potato waste by lowering the dissolved organic solids content have been explored on a laboratory scale. The chemical oxygen demand (C.O.D.) of waste filtrate was reduced from about 4000 to about 600 by batch or continuous fermentations at 30° C., with activated sludge inocula and an abundant supply of air. By combining a 24-hour batch propagation and acid coagulation (at pH 3), the C.O.D. of the waste filtrate was reduced to about 200, or 5 percent of the original value.

Although a relatively large quantity of air was aupplied during these laboratory experiments, it may be possible to reduce such air requirement. It is believed that this new approach to the potato starch factory waste problem should be followed up with laboratory and pilot-plant studies directed in part toward better aeration. More efficient aeration would make the microbiological process more promising.

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